2000

Evaluation of Hot Sauce® as a Repellent for Forest Mammals

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Abstract Foraging by forest mammals can be significantly detrimental to reforestation efforts. Repellents may offer a nonlethal solution for some situations. Hot Sauce® animal repellent uses capsaicin, a trigeminal irritant that should be aversive to most mammals. We conducted a series of tests evaluating the impact of Hot Sauce on foraging by 5 species of forest mammals. In our first study, we examined its potential to reduce browsing by black-tailed deer (*Odocoileus hemionus*). Damage to Western redcedar seedlings (*Thuja plicata*) was initially reduced with application of a 6.2% Hot Sauce solution, but efficacy began to decline after 2 weeks. Big Game Repellent Powder® reduced deer damage to redcedar for the entire 6-week study ($F \geq 143.9$, $P \leq 0.01$). Two-choice pen tests evaluated 0.06, 0.62, 3.1, and 6.2% Hot Sauce solutions as a repellent for pocket gopher (*Thomomys mazama*), porcupine (*Erethizon dorsatum*), and mountain beaver (*Aplodontia rufa*). Mountain beavers were not repelled by any concentration of Hot Sauce ($F \leq 1.94$, $P \geq 0.18$). Pocket gophers were repelled moderately by the 0.62, 3.1, and 6.2% concentrations, but even the 6.2% solution rarely reduced consumption below 50% of the food available. Porcupine foraging was reduced >48% by all repellent concentrations ($F \geq 7.08$, $P \leq 0.04$). Beavers (*Castor canadensis*) were not repelled consistently by Hot Sauce in multiple-choice tests of the 0.06, 0.62, and 6.2% solutions. Although Hot Sauce effectively repelled some species, at a cost of $12.25/gallon for the 6.2% repellent solution, it may not be cost-effective for most situations. Additionally, our data indicate there may be difficulties with product durability under field conditions.

Key words beaver, capsaicin, deer, Hot Sauce®, mountain beaver, pocket gopher, porcupine, repellents

Foraging by forest mammals can be significantly detrimental to reforestation efforts in the United States (Borrecco and Black 1990, Black 1992, Hygnstrom et al. 1994, Conover et al. 1995). Problems with forest mammals also include damage to riparian areas and ornamental plants (Black 1992, Hygnstrom et al. 1994). Although much of the damage occurs to seedlings and younger trees, wildlife also kill and deform older trees by foraging on tree bark (Black 1992, Hygnstrom et al. 1994, Conover et al. 1995). The traditional response to these problems has been to reduce population densities or to remove specific problem animals. However, population reduction is usually only a short-term solution because treated areas are repopulated quickly through reproduction or immigration. In some situations, chemical repellents may be an effective nonlethal alternative to reduce wildlife damage to plants.

One class of chemical repellents with good potential for use with a wide variety of mammals is trigeminal irritants (Mason et al. 1991). Trigeminal irritants stimulate the trigeminal pain receptors in the mucus membranes of the eyes, nose, mouth, and intestinal tract. Because trigeminal irritants induce a "pain" response, they are aversive to most mammalian species (Mason et al. 1991). Capsaicin is one such mammalian trigeminal irritant and is

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the active ingredient in Hot Sauce® animal repellent (Miller Chemical and Fertilizer Corp., Hanover, Penn.).

Wildlife response to Hot Sauce repellent has been mixed. A 0.062% concentration of Hot Sauce failed to reduce foraging by woodchucks (*Marmota monax*) on leaves of acorn and zucchini squash (Swihart and Conover 1991). The same 0.062% concentration had low to intermediate effectiveness on deer (*Odocoileus* spp., Harris et al. 1983, Palmer et al. 1983, Conover 1984). Andelt et al. (1994) related repellency to concentration of capsaicin, where a 0.062% concentration (1X) of Hot Sauce did not deter deer, a 0.62% (10X) concentration had intermediate results, and a 6.2% (100X) concentration had the greatest efficacy but was not completely effective. Deer were given new twigs daily, so the duration of any repellent effect was unknown. However, daily consumption of treated twigs did increase during the 5 days of the study. In a similar study, the 1X concentration of Hot Sauce did not repel elk (*Cervus elaphus*), but the 6.2% concentration deterred all satiated elk and 7 of 9 hungry elk (Andelt et al. 1992). The current Hot Sauce label includes provisions for using the 10X and 100X concentrations with deer and elk.

At present only limited data are available on the impact of any capsaicin concentration on many forest mammals. Consequentially, we initiated a pen study under natural weather conditions to determine the extent and duration of black-tailed deer (*Odocoileus hemionus columbianus*) response to the 100X concentration of Hot Sauce. We also evaluated the potential of various concentrations of Hot Sauce to reduce feeding by mountain beaver (*Aplodontia rufa*), pocket gopher (*Thomomys mazama*), porcupine (*Erethizon dorsatum*), and beaver (*Castor canadensis*).

Methods

Black-tailed deer

We placed the resident herd of black-tailed deer in 4 pens with 3-4 deer per group. Enclosures varied in size from 0.75 to 2 ha. Vegetation within the enclosures consisted primarily of Douglas-fir (*Pseudotsuga menziesii*), red alder (*Alnus rubra*), and associated understory vegetation. The deer had free access to pelleted food and water.

The 4 treatments used in the deer trials were 1) a solution of 6.2% Hot Sauce (100X) and 0.5% Vapor Gard®, 2) 0.5% Vapor Gard, 3) Big Game Repellent powder (BGR-P), and 4) control (untreated). We selected the 100X Hot Sauce formulation because this concentration was most effective in studies by Andelt et al. (1994). Vapor Gard is an antitranspirant spray recommended on the Hot Sauce label to improve the effective life of the repellent. BGR-P is an odor repellent that has been effective in several studies (Swihart and Conover 1990; Andelt et al. 1992, 1994; Milunas et al. 1994; Nolte et al. 1995; Nolte 1998). In this trial, BGR-P served as a positive control and as a standard for comparison. The BGR-P was purchased locally, and the Hot Sauce and Vapor Gard were donated by Miller Chemical and Fertilizer Corp.

We established 4 test plots in each pen. Each plot consisted of 4 rows of 3 Western redcedar (*Thuja plicata*) trees 0.5-1.0 m tall. Test plots were ≥25 m apart, and there was 1 m between seedlings within each plot. We randomly assigned treatments to test plots within each pen. We planted seedlings in the test plots immediately prior to treatment. We applied Hot Sauce and Vapor Gard solutions to all plant surfaces with a hand-held spray bottle until product started to run off the needles. We applied BGR-P by first misting all plant surfaces with water and then dusting the plants with the repellent powder.

Browsing damage generally consisted of terminal damage and a few bites taken from lateral foliage or complete defoliation. Therefore, our measures of damage included damage to the terminal bud and the number of lateral bites for each seedling. We limited lateral bite counts to a maximum of 25 because after 25 bites the seedlings were usually defoliated. We regarded uprooted seedlings as completely defoliated and thereafter recorded them as having terminal damage and >25 bites. The evaluation criteria were consistent across treatments and provided a means to assess 1) number of damaged seedlings, 2) number of seedlings with damage to the terminal bud, 3) mean number of lateral bites taken, and 4) number of completely defoliated seedlings (25 bites). Although these evaluation measures were interrelated, we reported all 4 criteria because they reflect different levels of damage intensity. We examined seedlings for browse damage at 24 and 48 hours post-treatment and at 1-week intervals thereafter for 6 weeks, at which time all of the Hot Sauce-treated seedlings had ≥25 bites. We obtained daily rainfall records from the Washington Department of Natural Resources' Miller Forest Nursery, located adjacent to the test site.

Mountain beaver (*Aplodontia rufa*) is one of several species responsible for damage to trees in the Pacific Northwest.

We analyzed data using a repeated measures analysis of variance and used general linear model (GLM) analyses to test for differences among treatments within a time period when significant time× treatment interactions were found. We used the SAS data analysis software for all analyses (Cody and Smith 1991, SAS Institute Inc. 1992).

Mountain beaver

We housed adult mountain beavers (10) in individual covered outdoor pens (3 × 3 m) that contained a simple artificial burrow system. Each system consisted of a series of 3 polyethylene trash cans (76 L) connected by corrugated plastic pipes (10 cm diam × 35 cm). We placed 2 goal boxes (76-L trash cans) at opposite corners of each pen. Throughout all tests, animals had free access to water and pelleted food.

A series of 2-choice tests evaluated relative preference between apple pieces treated with the Hot Sauce-Vapor Gard combination and untreated apple pieces. We tested repellent solutions containing 0.062% (1X), 0.62% (10X), 3.1% (50X), and 6.2% (100X) Hot Sauce in a series of consecutive experiments using increasing Hot Sauce concentrations. The 1X and 10X Hot Sauce formulations also contained 0.5% Vapor Gard. The 50X and 100X Hot Sauce formulations contained 2% Vapor Gard. The 2% concentration of Vapor Gard is greater than that recommended by the label and used in the deer trials. Data from the deer trials indicated that there might be problems with the 100X repellent being washed off plant surfaces. The manufacturer recommended increasing the Vapor Gard concentration to 2% in solutions with the 50X and 100X Hot Sauce concentrations. Therefore, we used the 2% concentration of Vapor Gard in this test and in all other tests with the 50X and 100X Hot Sauce solutions. One mountain beaver died after the test of the 1X formulation, and there were only 9 animals in subsequent tests with the 10X, 50X, and 100X formulations. There was no evidence indicating that the animal's death was related to the test materials.

All animals had a 4-day adaptation period before the test. Every morning of the adaptation period, each animal received 20 untreated 1-cm^3 apple cubes in both of their goal boxes. Animals had unlimited access to the goal boxes. We recorded the number of apple cubes remaining at 3, 6, and 24 hours daily. We considered any apple cubes removed from the goal boxes consumed. We conducted the 2-choice tests on 4 consecutive days immediately after the adaptation period. During the 2-choice tests, amount of food was identical to the adaptation period, but the apple cubes in one goal box had been dipped in the Hot Sauce-Vapor Gard combination and allowed to drain before being presented to the animals. The food in the remaining goal box was untreated. We randomly assigned treatments to goal boxes within each pen on the first day of the experiment and alternated treatment location on subsequent days. We analyzed data using a 2-way repeated measures analysis of variance.

Pocket gopher

We housed experimentally naive adult pocket gophers (12) in individual cages (43 × 28 × 28 cm). Pocket gophers accessed test foods via a "T" maze constructed from clear PVC pipe (5.1 cm diam) attached to each nest box. The nest box was the start point, and goal boxes were located at opposite sides of the decision point. Sections of pipe (1 m) separated the nest box and goal boxes from the decision point. The clear-plastic goal boxes (25.4 × 25.4 × 10.2 cm) had a removable lid and a side opening for the PVC pipe. The quantity of food placed in each goal box and the experimental design were identical to those used for mountain beaver. We analyzed data using a repeated measures analysis of variance. We used general linear model (GLM) analyses to test for differences among treatments within a time period when significant time× treatment interactions occurred. One pocket gopher escaped during the test of the 100X formulation, and we only used data from the remaining 11 animals in the analysis for this test.

Porcupine

We individually housed experimentally naive adult porcupines (4) in covered outdoor pens (3 × 3 m) containing a nest box, food dish, and water bowl. Two additional food dishes placed at opposite corners (1 bowl/corner) within each pen served as "goal boxes." We placed one-half of a peeled and cored apple, divided into 8 segments, into each bowl. Some porcupines picked up apple pieces and dropped them, uneaten, beside the bowl. We regarded all uneaten apple pieces found within 30 cm of the food bowls as present and not consumed. All other facets of experimental design, including the adaptation period, were as described for mountain beavers and pocket gophers. We analyzed data using a repeated measure analysis of variance.

Porcupines were greatly repelled by the 50X and 100X concentrations of Hot Sauce in the 2-choice trial, so we conducted an additional 1-choice trial for each concentration. The 1-choice test was similar to the procedures described for the 2-choice test except that there was only 1 goal box (dish) for apple pieces and all 8 apple pieces in the box received the same treatment. A 4-day pretreatment period with untreated food (1/2 apple divided into 8 pieces) in the goal box was immediately followed by a 4-day treatment period with treated food in the goal box.

Beaver

We used 8 adult beavers in the initial test. Throughout the trial, animals received untreated apples, carrots, and free access to pelleted feed and fresh water. Each pen contained a rack supporting PVC rings designed to hold 1-m-long and 7- to 10-cm-diameter cottonwood (*Populus* spp.) segments at 0.5-m intervals. Beavers had access to untreated cottonwood stems placed in these racks for >1 month prior to the start of the experiment. At the beginning of the experiment, we randomly assigned treatments (control, 1X, 10X, and 100X Hot Sauce) to pairs of adjacent stems. After 6 days, we assigned one of the following damage scores to each stem: 1) no damage, 2) 10% of the diameter of the stem girdled, 3) 10%–33% of the diameter of the stem girdled, 4) 33%–66% of the diameter of the stem girdled, 5) 66%–90% of the diameter of the stem girdled, 6) >90% of the stem segment girdled or >50% of the stem chewed through, 7) 100% of the diameter of the stem segment girdled along more than 33% of the length of the stem or the segment completely chewed through. At the end of 6 days, we repeated the procedure. We evaluated beaver response to treatments using Wilcoxon rank sum analysis on the data from day 6 (Cody and Smith 1991, SAS Institute Inc. 1992).

We conducted a second trial using 4 of the beavers while they were housed in a communal enclosure. As with the first test, beavers received untreated apples, carrots, and free access to pelleted feed and fresh water throughout the trial. We placed 5 racks, 0.5-m-long sections of lumber with holes for holding seedlings with ≤1.5-cm-diameter stems, along the walls of the enclosure. Each rack contained 3 Western redcedar seedlings 0.75–1 m tall. Western redcedar is one of several tree species that beavers will take from reforested riparian areas. During the 3-day acclimation period, each rack contained untreated seedlings. The treatment period began immediately after the acclimation period. We treated all seedlings at the beginning of the treatment period. All seedlings within a rack received the same treatment. At the end of every 2-day period, we replaced the old seedlings with new seedlings that had received a different treatment. We rotated treatments (control, 1X, 10X, 50X, and 100X) among racks and periods so that each rack received each treatment for 1 period. We recorded the number of cut stems at the end of each 2-day period. We analyzed data using an analysis of variance (Cody and Smith 1991, SAS Institute Inc. 1992).

None of the beaver pens were covered. Therefore, the cottonwood stems and redcedar seedlings were exposed to any precipitation that occurred. We obtained daily rainfall records from the Washington Department of Natural Resources' Miller Forest Nursery located adjacent to the test site.

All animal care and use for this study was approved by United States Department of Agriculture, Animal and Plant Health Inspection Service, Wildlife Services, National Wildlife Research Center, Institutional Animal Care and Use Committee in research protocol QA-544.

Results

Black-tailed deer

Weekly rainfall totals were 1.0, 7.4, 4.5, 5.9, 7.2, and 6.2 cm for weeks 1–6, respectively. There was a significant time × treatment interaction for the experiment ($P \leq 0.01$). There were no differences

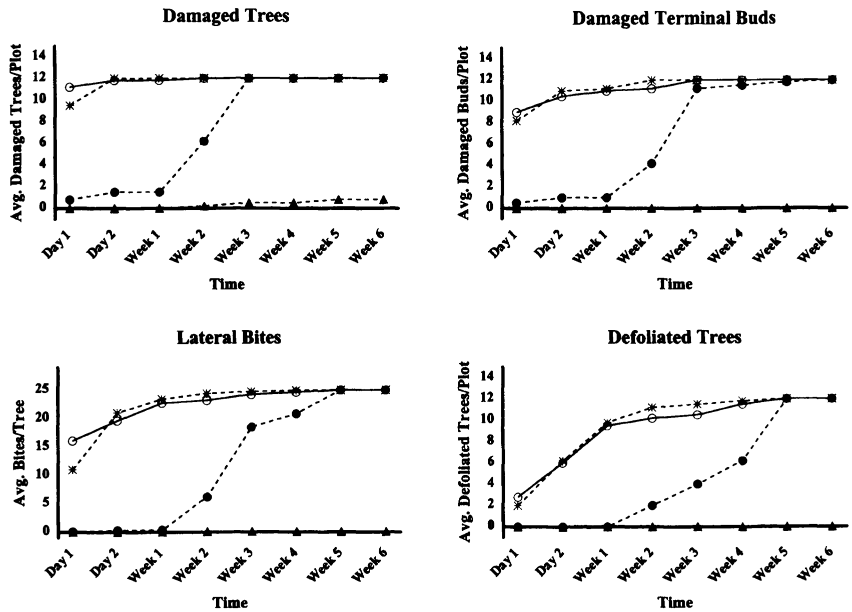

Figure 1. Pattern of 4 types of black-tailed deer damage to Western redcedar seedlings during a 4 February-16 March 1997 test of Hot Sauce animal repellent. Seedlings were untreated or treated with Big Game Repellent Powder (BGR-P), 0.5% Vapor Gard solution (Vapor Gard), or a 0.5% Vapor Gard and 6.2% Hot Sauce solution (Hot Sauce).

between untreated seedlings and seedlings treated with Vapor Gard in any of the damage indices ($F \leq 1.72, P \geq 0.22$, Figure 1). On day 1, number of defoliated trees did not differ between BGR-P and Vapor Gard (defoliated $\geq$25 bites, $F=3.19, P=0.11$). For all other damage measures on day 1 and all damage measures for the remainder of the experiment, damage to BGR-P seedlings was less than all untreated and Vapor Gard seedlings ($F \geq 6.03$, $P \leq 0.04$).

Deer response to Hot Sauce varied during the experiment. There were no differences between Hot Sauce and BGR-P on day 1 ($F \leq 0.25, P \geq 0.63$). On day 2 and week 1, there were more damaged Hot Sauce seedlings than BGR-P seedlings ($F \geq 8.88$, $P \leq 0.02$), but there were no differences between Hot Sauce and BGR-P in number of damaged terminal buds, defoliated trees, or lateral bites ($F \leq 1.17, P \geq 0.22$). During week 2, number of damaged seedlings and seedlings with damaged terminal buds was greater for Hot Sauce than BGR-P ($F \geq 6.67$, $P \leq 0.03$), but there was still no difference between Hot Sauce and BGR-P in number of lateral bites or defoliated seedlings ($F \leq 2.69$, $P \geq 0.14$). After week 2, all damage measures were greater for Hot Sauce than for BGR-P ($F \geq 6.86, P \leq 0.03$).

As with BGR-P, on day 1, number of defoliated seedlings did not differ among Hot Sauce, Vapor Gard, and control ($F=3.19$, $P=0.11$). All other forms of damage for day 1 and all forms of damage from day 2 through week 2 were less for Hot Sauce seedlings than for Vapor Gard or control seedlings ($F \geq 7.62; P \geq 0.02$). During weeks 3 and 4, there was no difference in number of damaged seedlings among Hot Sauce, Vapor Gard, and control ($F < 0.01$, $P > 0.99$). However, number of damaged terminal buds, lateral bites, and defoliated seedlings was still less for Hot Sauce than for Vapor Gard or control ($F \geq 4.91, P \leq 0.05$). After week 4, there was no difference in any of the damage measures among Hot Sauce, Vapor Gard, or control seedlings ($F \leq 2.00, P \geq 0.19$).

Mountain beaver

Number of apple pieces consumed by mountain beavers was not reduced by any concentration of the repellent ($F \leq 1.94, P \geq 0.18$).

Pocket gopher

There was not a time×treatment interaction for the base concentration ($F \geq 2.13, P \leq 0.5$), but there was a time×treatment interaction for the 10X, 50X, and 100X concentrations ($F \geq 5.09, P \leq 0.01$). The 1X concentration of Hot Sauce did not reduce feeding ($F=3.3, P=0.08$, Figure 2). The 10X concentration reduced pocket gopher consumption of apples on day 1 and day 4 ($F \geq 4.78$, $P \leq 0.04$), but did not reduce damage on day 2 or day 3 ($F \leq 2.40, P \geq 0.14$). Both the 50X and 100X concentrations reduced feeding ($F \geq 17.41$, $P < 0.01$). However, the reduction in apples consumed was relatively low (Figure 2).

Porcupine

Number of apple pieces consumed was reduced by all Hot Sauce concentrations ($F > 7.08$, $P \leq 0.04$, Figure 3). During the 50X and 100X tests, 3 of the 4 porcupines did not eat any treated apple.

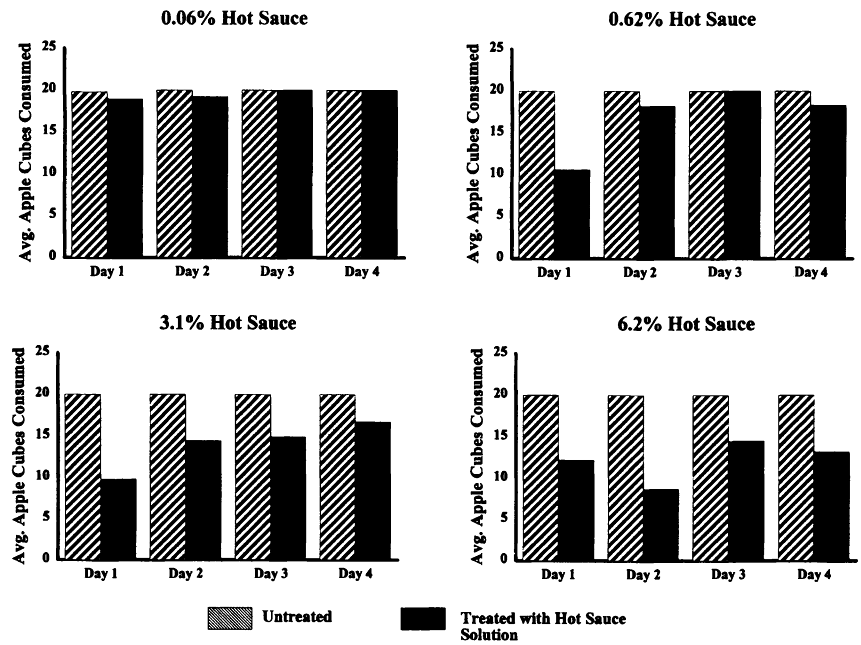

Figure 2. Average daily pocket gopher consumption of 1-cm3 apple cubes treated with 0.06 (1X), 0.62 (10X), 3.1 (50X), or 6.2% (100X) Hot Sauce solutions used in 2-choice pen tests.

During the 1-choice tests of the 50X and 100X concentrations, all porcupines ate all 8 untreated pieces of apple each day of the pretreatment period and did not eat any apple during the treatment period.

Beaver

In the first trial, beaver use of stems was low. Only 4 of the beavers chewed on stems during the first period. During the second period, 1 animal did not chew on stems and 2 animals only sampled stems (damage scores ≤ 2). All treatments resulted in reduced damage scores (control $\bar{x}=3.2$, SE=0.4; 1X $\bar{x}=2.3$, SE=0.4; 10X $\bar{x}=2.1$, SE=0.3; 100X $\bar{x}=2.1$, SE=0.3; $Z\geq 1.82$; $P\leq 0.06$). There was no difference in response among the 3 levels of treatment ($Z\leq 0.23$, $P\geq 0.82$). Rainfall during the study period was 4.1 cm.

During the test with cedar seedlings, there was no difference among treatments in number of stems that were cut ($F=0.65$, $P=0.63$). The beavers did not always appear to be eating seedlings. Cut seedlings were found on the ground beside the racks and in the beaver's nest boxes. Rainfall during the test period was 10.6 cm.

Discussion

In the black-tailed deer study, plots with Hot Sauce seedlings had fewer damaged terminal buds, lateral bites, and defoliated seedlings than untreated trees for the first 2 weeks. However, the period of efficacy was much shorter for Hot Sauce than for BGR-P, which reduced all forms of damage for the duration of the experiment. The efficacy of Hot Sauce repellent for the first week of the deer trial and subsequent decline in response after 2 weeks illustrated the importance of running long-term repellent studies under field conditions. Studies conducted by Andelt et al. (1994) and Lutz and Swanson (1997) indicated that Hot Sauce was as effective as or more effective than BGR-P in reducing deer consumption of apple twigs and pelleted feed. However, in both studies, the test food was never exposed to natural weather conditions for more than 24 hours. The early success of Hot Sauce in our deer study was similar to the findings of Andelt et al. (1994) and Lutz and Swanson (1997) and appeared to indicate that capsaicin can be an effective active ingredient. The subsequent failure may have been attributable to the repellent washing off or "breaking down" under field conditions. Conversations with the manufacturer indicated that the 6.2% concentration of Hot Sauce may prohibit a 0.5% concentration of Vapor Gard from forming an effective protective layer on the plant. Our findings are in

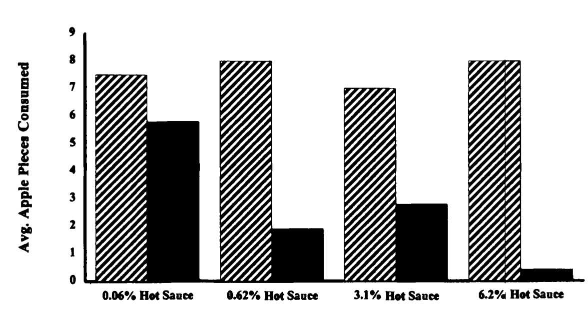

Figure 3. Average porcupine consumption of 1-cm3 apple cubes treated with 0.06 (1X), 0.62 (10X), 3.1 (50X), or 6.2% (100X) Hot Sauce solutions used in 2-choice pen tests.

Figure 4. Data collection during outdoor pen tests of deer response to Hot Sauce repellent.

contrast to tests conducted in Colorado, where the 100X concentration of Hot Sauce significantly reduced elk damage to aspen 10 weeks after treatment (W. F. Andelt, Colorado State University, Fort Collins, personal communication). However, total precipitation during the 10-week Colorado study was <8 cm, whereas the total rainfall in our study after only 2 weeks was 8.4 cm and was 32.2 cm by the end of the study. Field exposure trials or environmental chamber tests could be used to identify the nature of the product loss over time.

There was considerable interspecific variation in response to Hot Sauce in the pen trials. Mountain beavers did not respond to even the greatest repellent concentration. It is possible that they are more tolerant of chemicals avoided by other mammals. For example, in food habits studies, mountain beavers have been observed foraging on plants like tall larkspur (*Delphinium glaucum*), which is known to be toxic to livestock (Voth 1968, O'Brian 1981, Cheeke 1985). Pocket gophers were only moderately repelled by the 6.2% repellent formulation. In contrast, porcupine foraging was reduced >48% by all concentrations of the repellent. The response of porcupines to the 50X and 100X concentrations during the 1-choice tests indicates good potential for using capsaicin as a porcupine repellent.

Beaver response to the repellent varied. Findings from the test using treated cottonwood stems indicated that beavers are at least moderately repelled by Hot Sauce, but Hot Sauce did not influence foraging on Western redcedar seedlings. In a subsequent study by T. DuBow (unpublished data, 1999), beavers were not repelled by the 100X concentration of Hot Sauce on willow twigs. It is possible that the difference in beaver response to treated cottonwood stems and redcedar seedlings was attributable to differences in the type of damage recorded. Only one bite was required to cut cedar seedlings, and beavers were not required to eat seedlings. In contrast, in the test using cottonwood stems, beavers were required to spend more time chewing on, and presumably eating, tree bark. A similar mechanism may explain the beaver response to willow twigs in the study by DuBow. Alternatively, willow is a preferred beaver food, and given that repellent efficacy is relative to the palatability of the food item, the lack of response may be associated with beaver preference for this food (Aleksiuk 1970, Henry and Bookhout 1970, Allen 1983).

Hot Sauce appears to have potential to protect plants from a few of the animal species tested. Hot Sauce was registered for use only to reduce deer damage to trees, although there was a provision for mixing Hot Sauce with petroleum jelly to protect maple syrup collecting equipment from porcupine damage. Hot sauce effectively reduced porcupine foraging in our pen studies and may have potential to reduce porcupine damage to signs and structures. The cost of the repellent, $12.25/gallon in a 100X Hot Sauce solution, may limit the situations where Hot Sauce is a cost-effective alternative. Hot Sauce may not be cost-effective for use with species that are only slightly or moderately repelled. Finally, there is the issue of product durability under field conditions. Additional research is needed to determine durability of Hot Sauce under carefully monitored environmental conditions. It may be necessary to increase the amount of adhesive agent, as recommended by the manufacturer for use in our study, or to switch adhesive agents. Optimal repellent formulation requires an effective active ingredient and a delivery system that provides good product durability under field conditions.

Acknowledgments: We would like to thank T.W. Otto, J.W. Theade, and T. B. Veenendaal for assistance with this project. Thanks are also due M. Fall and A. C. Wagner for review of this manuscript.

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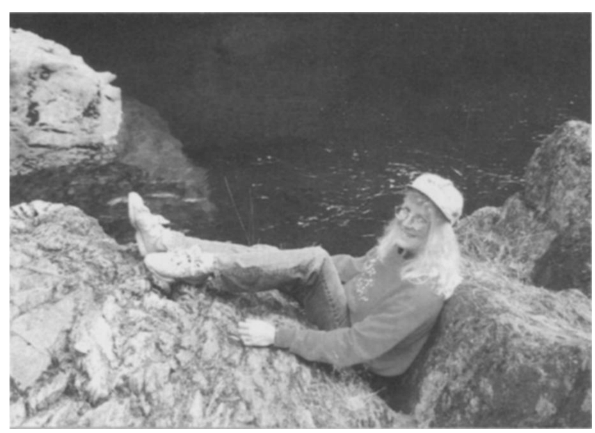

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Associate Editor: *San Julian*